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Report No. 216

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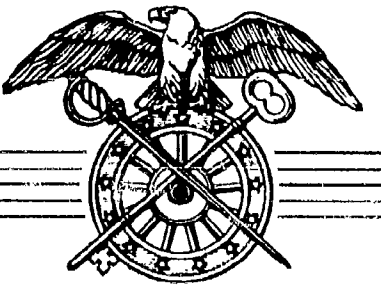

Research and Development Division
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Department of the Army
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Research and Development Division

Environmental Protection Division
Report No. 216

TRUNK INCLINATION IN CARRYING LOW AND HIGH PACKS OF VARIOUS WEIGHTS

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ABSTRACT

The effect of low and high packs of various weights on trunk inclination was studied. The loads used in this study were 0, 20, 40, 60, and 80 pounds. Still pictures were taken while the subjects were standing and while they were walking on horizontal, downgrade, and upgrade planes on a motor-driven treadmill. The speed of the treadmill, for walking, was 2.8 mph. During walking, two body positions were photographed: when the subject's center of gravity was at the lowest level, and when the subject's center of gravity was at the highest level. A total of 600 pictures of eight subjects was analyzed to determine degrees of trunk inclination. Although there was a definite trend showing that the low pack caused greater trunk inclination, the difference between the mean angles of trunk inclination caused by the high and low packs was not statistically significant. The latter probably depended on the small number of subjects used in this study. A lesser degree of trunk inclination with a high pack may be one of the reasons why most men prefer a high pack to a low one.

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FOREWORD

In the first report in this series on the Physiology of Load-Carrying, findings were presented on the angle of forward inclination of the trunk with high back, low back, and waist pack loads. The investigators in the Department of Physiology at Springfield College have made a much more extensive study of the inclination resulting from high and low pack loads and have extended the studies to include the effects of standing and walking on different grades.

An explanation is offered in this study for the apparent preference of most individuals for carrying weights on the shoulder or on the high back, rather than on the low portion of the back. While further study will be required to establish it as a general principle, it appears in most studies that loads which enforce a deviation from the normal posture are considered uncomfortable.

These studies at Springfield College contribute not only background information on load-carrying in general, but also suggest methods which may be useful in the study of experimental pack designs.

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TRUNK INCLINATION IN CARRYING LOW AND HIGH PACKS OF VARIOUS WEIGHTS

1. Introduction

a. More men carrying packs prefer the high pack position to the low pack position. When asked why, the response indicates it is more comfortable and less fatiguing. This preference cannot be explained, however, by energy cost studies. Daniels, et al* have shown that there is little or no difference in energy expenditure when carrying the high or the low pack. The reason physiological findings do not substantiate subjective findings may be because of localized fatigue which does not materially affect energy expenditure.

b. Lippold and Naylor** electromyographically studied the effect of load position upon the activity of the trunk muscles. Two positions were investigated: high on the back and low, when the load was carried around the pelvis. They found that the high position of the load caused a greater activity of the back muscles than the low position. Their explanation of this observation was that the higher the center of gravity (body weight and load combined), the greater the body instability and, therefore, the more muscle effort is required to maintain equilibrium.

c. While this explanation is logical, it may be asked what the effect will be of the degree of trunk inclination on the degree of comfort or discomfort in carrying a pack placed, not around the pelvis, but low on the back. A greater trunk inclination will require more muscular effort than a lesser degree of inclination and, therefore, will be more fatiguing.

d. Braune and Fischer*** experimented on three subjects by having

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*Daniels, F., Jr., J.H. Vanderbie and C.L. Bommarito. Energy cost of carrying three load distributions on a treadmill. OQMG. EPB Rpt No. 203, March 1953.

**Lippold, O.C.J. and P.F.D. Naylor. The design of load carrying equipment for the soldier in battle. Great Britain. Army Operational Research Group Report No. 11/50, 1950.

***Braune, W. and O. Fischer. The center of gravity of the human body as related to the equipment of the German Infantry. Saxony. Royal Academy of Sciences. Tr. Mathematical-Physical Class. No. 7, 1889. Technical Data Library. Wright Air Development Center. Translation No. 379, October 16, 1944.

them walk and stand on inclined planes. When the angle reached 32 degrees, subjects carrying a regulation pack on the back could not walk unless the pack was placed on the head and the cartridge belt around the neck. The subjects were able to stand without a pack on an upgrade with a slope of 47 to 49 degrees, while with a pack on the back the limit was 41.5 to 42 degrees. When the pack was placed on the chest, the limit was 48 to 52 degrees. The investigators concluded that a higher position of the load is preferred in walking upgrade.

e. As a further proof of their conclusion, they called attention to an observation that Germans who live on the plains of that country carry packs in the center of the back, while those living in mountainous regions place the packs as high as possible, even on their heads.

f. Most foot soldiers prefer to carry the packs high on the back regardless of the terrain, and since many people who live on flat terrain prefer to carry the load on the head or as close to the shoulder level as possible, it has been decided to investigate the effect of position and weight of the pack upon the degree of trunk inclination in men standing and walking on horizontal, downgrade, and upgrade planes.

2. Materials and Methods

a. Materials

Eight male students of Springfield College were used as subjects. They ranged in age from 18 to 20 years, in height from 65 to 72 inches, and in weight from 118 to 230 pounds.

The pack was made from an Army five-gallon water can strapped to a packboard, this unit weighing 20 pounds empty. The pack was filled with lead shot until the total weight was 20, 40, 60, or 80 pounds.

The subjects performed on a motor-driven treadmill while pictures were being taken. Walking was done at a speed of 2.8 mph.

A manually-operated 35 mm. Robot sequence camera made by Otto Berning and Company, Schwelm-Westfalia, Germany, was used to take all the pictures for this study. The camera has a Tessar f/2.8 lens and shutter speeds up to 1/500 of a second.

A grid, eight feet by eight feet, with black silk tape every four inches vertically and horizontally was constructed and placed behind the treadmill to facilitate determination of trunk inclination.

b. Methods

Still pictures were taken while the subjects were standing and while they were walking on horizontal, downgrade, and upgrade planes. The angle for downgrade and upgrade walking was nine degrees. Each subject

was photographed with the high and low packs. During walking, only two body positions were photographed. The first position was when the subject's center of gravity was at the lowest level, and the second position was when the subject's center of gravity was at the highest level.

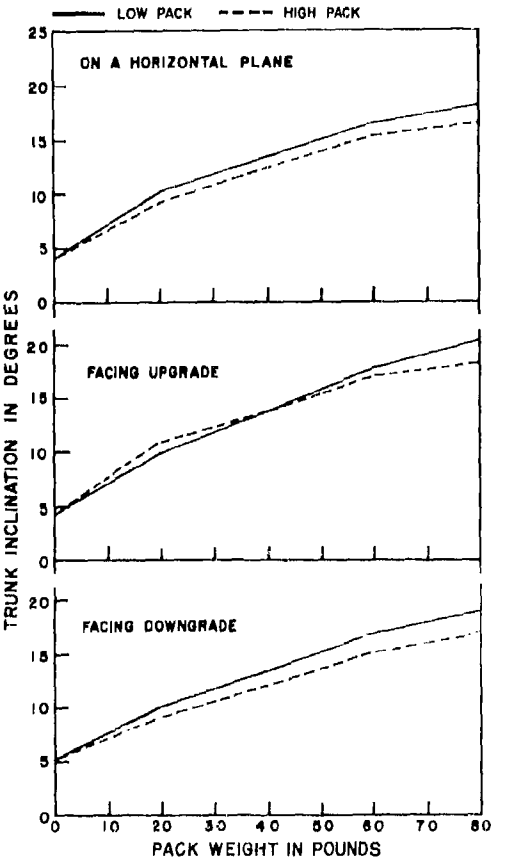
To facilitate finding the points of orientation, the subjects wore only athletic supporters and shoes, and circular black patches were pasted over the tragus and the greater trochanter of the femur.

To standardize further the testing procedure, all subjects walked 1.5 miles carrying a 40-pound pack just before being photographed. Since most of the subjects had never carried a pack before, this procedure enabled them to "get the feel" of the pack and establish a body position which they believed was the most comfortable while carrying the pack.

The measurements of changes in trunk inclination were made by projecting the negatives of the pictures on a screen and running a vertical line through the hip marking. A transparent protractor was placed over the picture on the screen, and the deviations of the longitudinal trunk axis from the vertical line passing through the hip marking were then measured. The trunk axis was represented by a line connecting the hip and the tragus markings. A total of 75 pictures was analyzed for each subject.

In order to determine if the trunk inclination changed as the subjects became fatigued, an exploratory study was conducted. Motion pictures were taken of two subjects who carried 60-pound packs for two hours. Pictures were taken at the beginning of the march and at 15-minute intervals, thereafter. Analysis of these films indicated that the subjects maintained the same posture throughout the entire two-hour period of march. Therefore, it was possible to take the still pictures of the subjects at the beginning of the march rather than having them walk for a long period of time before pictures could be taken. These motion pictures were also used to determine when the body's center of gravity was at the lowest level and when it was at the highest level.

FIGURE 1. DEGREE OF TRUNK INCLINATION IN STANDING WITH LOW AND HIGH PACKS OF VARIOUS WEIGHTS



3. Results

a. The mean angles of trunk inclination are graphically presented in Figures 1, 2, and 3. These figures show that, with

DEGREE OF TRUNK INCLINATION IN WALKING WITH LOW AND HIGH PACKS OF VARIOUS WEIGHTS

FIGURE 2: CENTER OF GRAVITY OF BODY AT LOWEST LEVEL

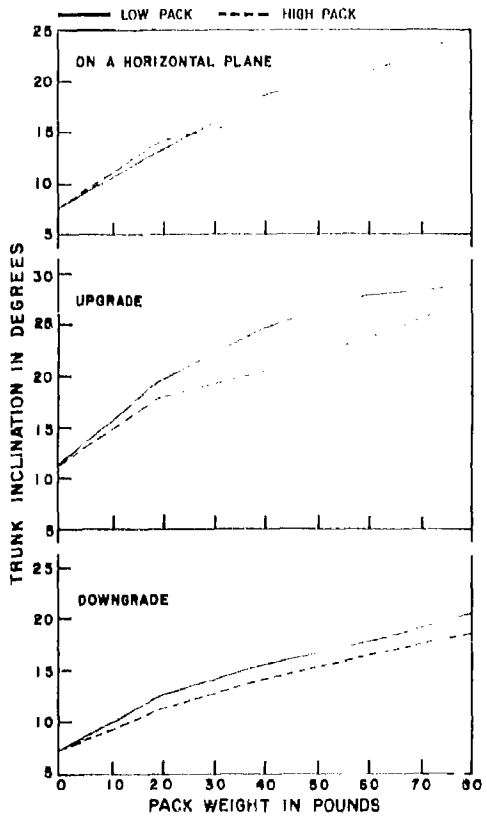
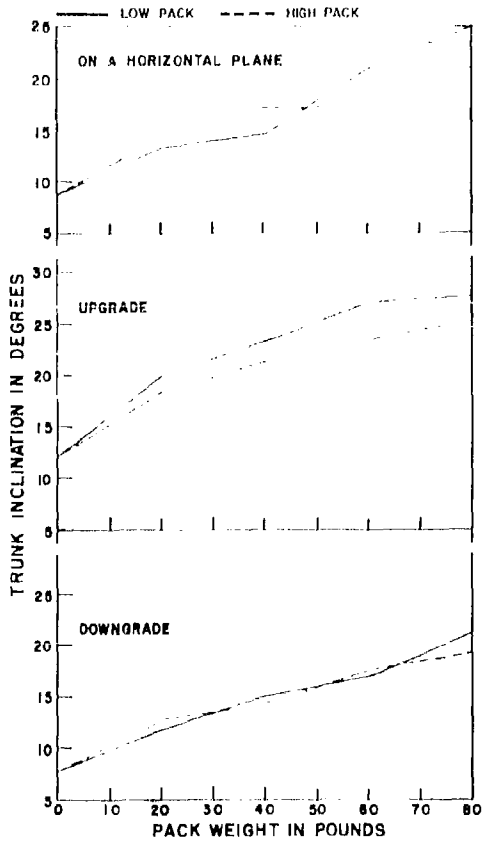


FIGURE 3: CENTER OF GRAVITY OF BODY AT HIGHEST LEVEL



a few exceptions, the low pack caused greater change in trunk inclination than did the high pack. These graphs also show that the greatest trunk inclination occurred during standing or walking upgrade, and the least during standing or walking downgrade. There was little difference between the degrees of trunk inclination when the subject stood on the horizontal or on the downgrade planes.

b. In Figures 4, 5, and 6, subjects are shown standing and walking on horizontal, upgrade, and downgrade planes. The effect of increase in pack weight on trunk inclination is clearly evident. It appears, also, that the low pack causes greater trunk inclination than does the high pack; however, the difference between the mean angles of trunk inclination caused by the high and low packs was not statistically significant. Complete statistical analysis of data appears in Tables I, II, III, and IV.

Figure 4: Body Positions in Standing and Carrying Low and High Packs of Various Weights (in pounds) on a Horizontal Plane

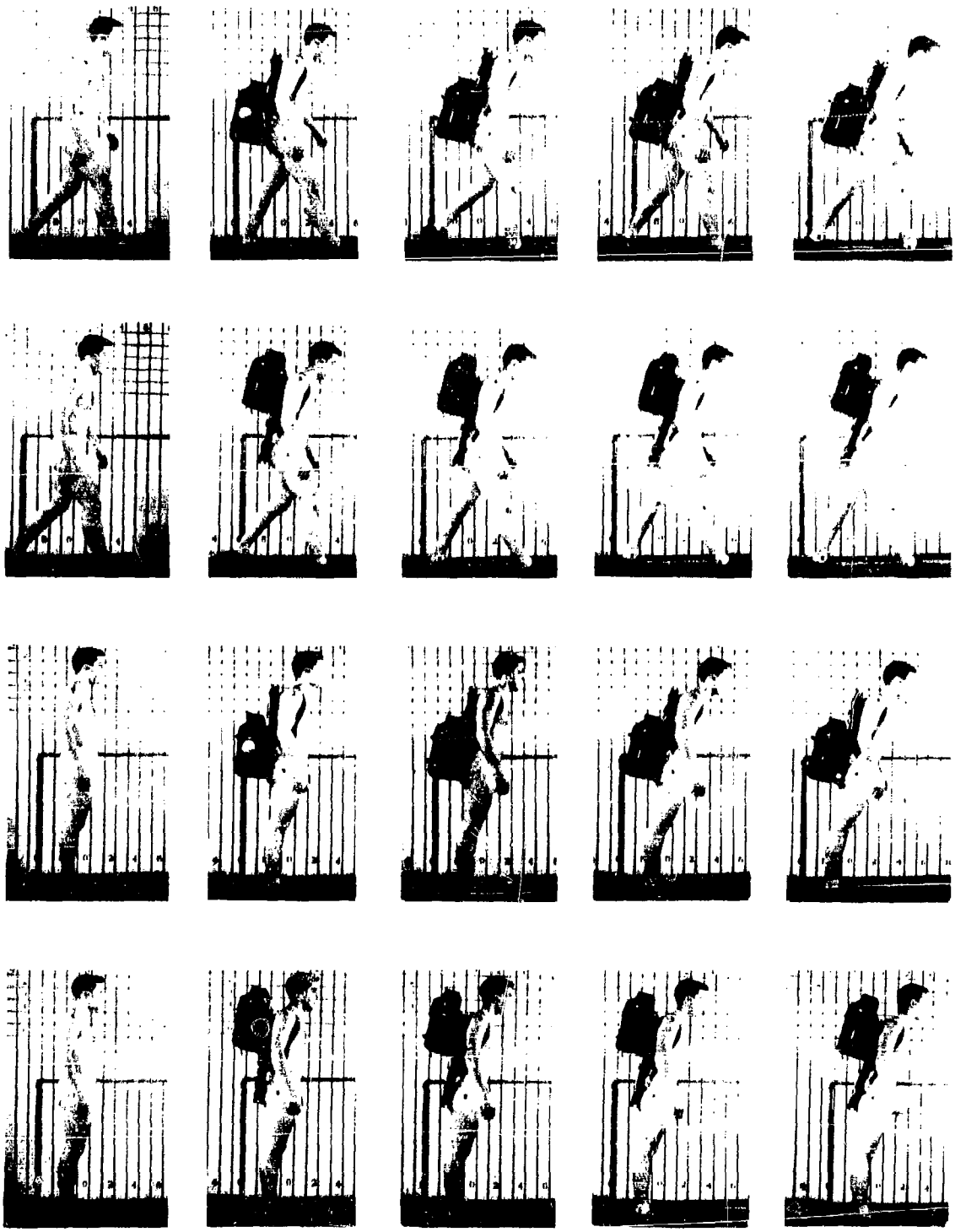


Figure 5: Body Positions in Standing and Carrying Low and High Packs of Various Weights (in pounds) on an Upgrade

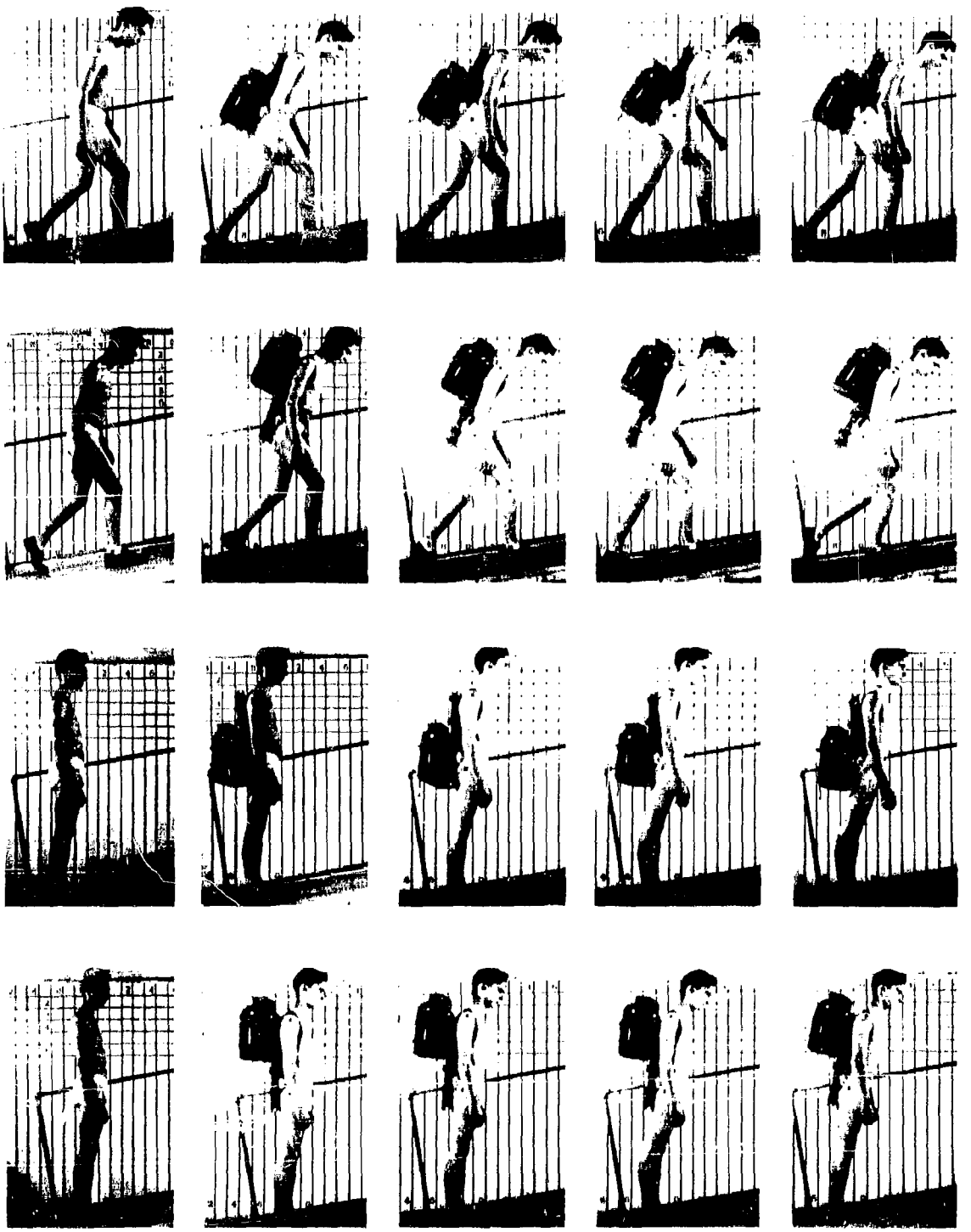


Figure 6: Body Positions in Standing and Carrying Low and High Packs of Various Weights (in pounds) on a Downgrade

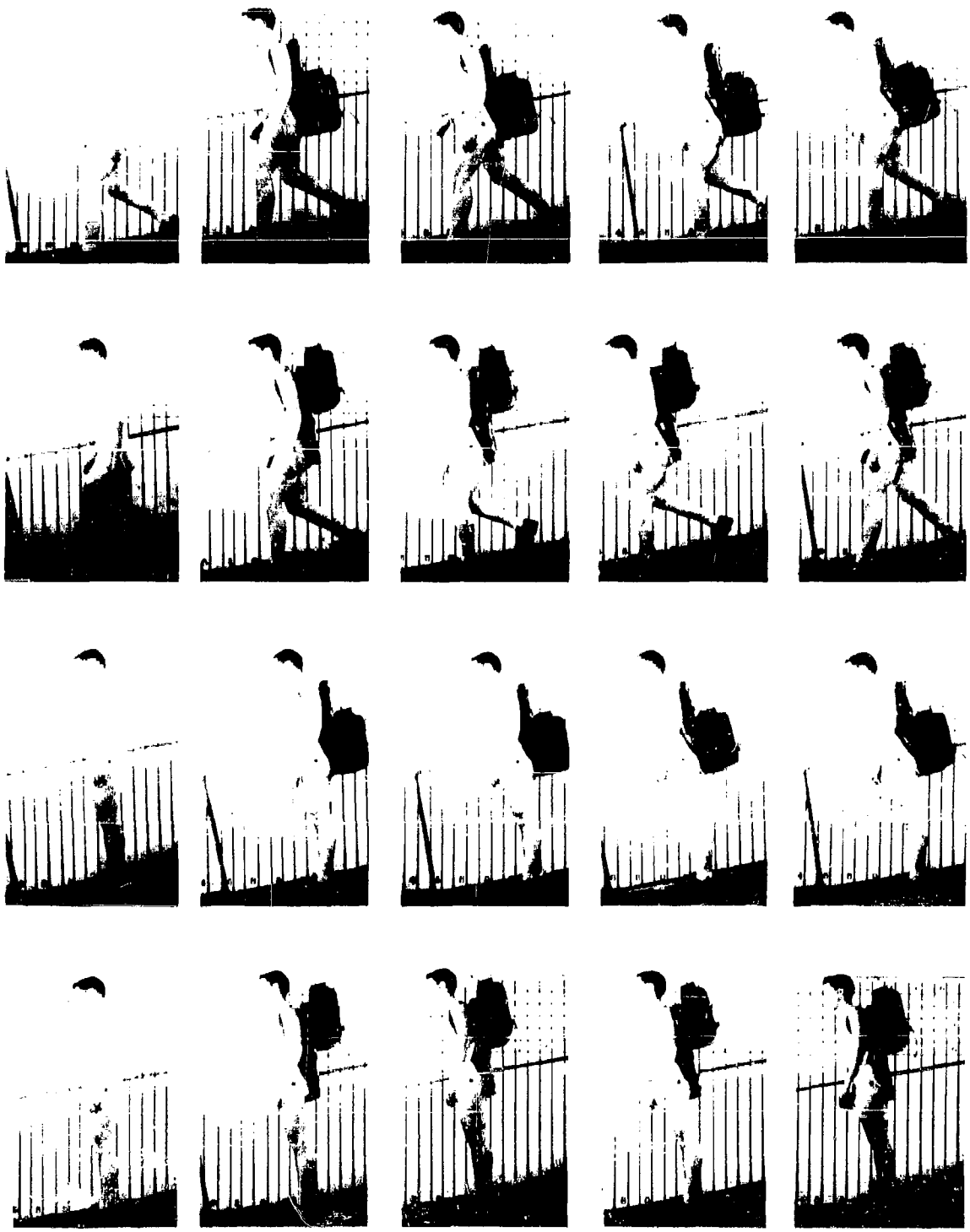


TABLE I: COMPARISON BETWEEN DEGREES OF TRUNK INCLINATION FOR LOW AND HIGH PACKS

Pounds	$\frac{D}{t}$	Horizontal Plane	Facing Upgrade	Facing Downgrade
Standing				
0	$\frac{D}{t}$	0 0	0 0	0 0
20	$\frac{D}{t}$	.62 .43	-.44 .32	.82 .58
40	$\frac{D}{t}$	1.00 .53	0 0	1.31 .58
60	$\frac{D}{t}$	1.43 .69	.50 .17	.63 .25
80	$\frac{D}{t}$	1.63 .61	1.25 .35	1.93 .59
Walking (Center of Gravity in the Low Position)				
0	$\frac{D}{t}$	0 0	0 0	0 0
20	$\frac{D}{t}$	-.19 .06	1.63 .46	.94 .38
40	$\frac{D}{t}$	1.75 .51	3.87 .96	1.50 .61
60	$\frac{D}{t}$	1.94 .61	4.00 .88	1.06 .29
80	$\frac{D}{t}$	2.87 .70	1.06 .22	1.94 .54
Walking (Center of Gravity in the High Position)				
0	$\frac{D}{t}$	0 0	0 0	0 0
20	$\frac{D}{t}$	-.81 .30	1.50 .45	-.25 .09
40	$\frac{D}{t}$	-.44 .35	1.88 .52	.12 .04
60	$\frac{D}{t}$	3.75 1.19	3.12 .86	-.06 .02
80	$\frac{D}{t}$	3.75 .85	2.69 .62	1.75 .53

D = Mean of degrees of trunk inclination with low pack minus the degree of trunk inclination with the high pack.

t = t-ratio.

TABLE II: EFFECT OF PACK WEIGHT ON DEGREES OF TRUNK INCLINATION OF EIGHT SUBJECTS IN STANDING

	Low Pack					High Pack				
Pounds	0	20	40	60	80	0	20	40	60	80
On a Horizontal Plane										
M	4.06	10.06	13.38	16.56	19.13	4.06	9.44	12.38	15.13	17.50
SD	2.15	2.82	3.87	4.91	5.64	2.15	2.91	3.59	4.35	5.04
SE_m	.76	.99	1.37	1.38	2.00	.76	1.03	1.27	1.54	1.78
Facing Upgrade										
M	4.50	10.19	13.81	17.75	20.13	4.50	10.63	13.81	17.25	18.88
SD	1.79	2.89	4.68	6.15	7.88	1.79	2.49	4.44	5.25	6.40
SE_m	.63	1.02	1.66	2.18	2.79	.63	.88	1.57	1.86	2.27
Facing Downgrade										
M	5.13	9.88	12.94	13.75	18.31	5.13	9.06	11.63	14.38	16.38
SD	2.67	3.02	5.18	5.88	8.41	2.67	2.62	3.66	4.12	3.96
SE_m	.95	1.07	1.83	2.08	2.98	.95	.93	1.30	1.46	1.40

4. Discussion

a. Normally, the center of gravity of the body lies over the feet and when a load is placed on the back, the center of gravity is moved backward. In order to bring the center of gravity forward to its "normal" position, the person must lean forward. In carrying the pack high on the back, it is easy to readjust the center of gravity by simply "hunching" the shoulders, whereas the only way of readjusting the center of gravity while carrying the low pack is by a greater degree of trunk inclination. Therefore, the body lean will be greater when carrying the low pack. Since greater trunk inclination results in greater muscle activity, it is obvious that the low pack will be more fatiguing.

b. Although the data collated in this study did not show a statistically significant difference between means of angles of trunk inclination caused by high and low packs, there is a definite trend for the low pack to cause greater trunk inclination than that caused by the high pack. The absence of statistical significance of difference in the degree of trunk inclination probably resulted from the small number of subjects used.

EFFECT OF PACK WEIGHT ON DEGREES OF TRUNK INCLINATION OF EIGHT SUBJECTS IN WALKING

TABLE III: CENTER OF GRAVITY OF BODY AT LOWEST LEVEL

	Low Pack					High Pack				
Pounds	0	20	40	60	80	0	20	40	60	80
	On a Horizontal Plane									
M	7.31	13.69	18.31	20.75	24.81	7.31	13.88	16.56	18.81	21.94
SD	4.40	5.54	5.83	7.10	8.69	4.40	6.22	7.77	5.48	7.72
SE_m	1.56	1.96	2.06	2.51	3.08	1.56	2.20	2.75	1.94	2.73
	Upgrade									
M	11.13	19.63	24.31	27.75	28.56	11.13	18.00	20.44	23.75	27.50
SD	6.36	7.15	8.10	10.21	9.36	6.36	6.92	8.05	7.83	8.36
SE_m	2.25	2.53	2.87	3.62	3.31	2.25	2.45	2.85	2.77	2.96
	Downgrade									
M	7.06	12.44	15.69	17.81	20.50	7.06	11.50	14.19	16.75	18.56
SD	4.19	3.74	6.02	8.53	8.37	4.19	5.91	3.53	5.96	5.73
SE_m	1.48	1.32	2.13	3.02	2.96	1.48	2.09	1.25	2.11	2.03

TABLE IV: CENTER OF GRAVITY OF BODY AT HIGHEST LEVEL

	Low Pack					High Pack				
Pounds	0	20	40	60	80	0	20	40	60	80
	On a Horizontal Plane									
M	8.81	13.44	17.06	21.44	25.00	8.81	14.25	17.50	17.69	21.25
SD	3.55	5.45	5.35	4.68	9.84	3.55	5.51	6.44	7.57	7.62
SE_m	1.26	1.93	1.89	1.66	3.48	1.26	1.95	2.28	2.68	2.70
	Upgrade									
M	12.56	20.13	23.63	27.06	28.44	12.56	18.63	21.75	23.94	25.75
SD	5.19	6.23	7.42	7.46	9.98	5.19	7.03	7.09	7.05	7.14
SE_m	1.84	2.21	2.63	2.64	3.53	1.84	2.49	2.51	2.50	2.53
	Downgrade									
M	7.94	12.44	15.00	17.75	21.44	7.94	12.69	14.88	17.81	19.69
SD	4.00	5.27	6.45	7.69	6.99	4.00	6.36	5.63	6.63	6.11
SE_m	1.42	1.87	2.28	2.72	2.48	1.42	2.25	1.99	2.35	2.16

5. Summary

a. The effect of low and high packs on trunk inclination was studied on eight subjects. The packs weighed 20, 40, 60, and 80 pounds. Still pictures were taken while the subjects were standing and while walking on horizontal, downgrade, and upgrade planes of a motor-driven treadmill, moving at a speed of 2.8 mph. From the pictures, changes in trunk inclination were determined.

b. In almost all instances, the low pack caused greater trunk inclination than did the high pack. The difference, however, was not statistically significant.

c. The greatest trunk inclination occurred during standing or walking upgrade, and the least during standing or walking downgrade. There was little difference between the degrees of trunk inclination when the subject stood on the horizontal or on the downgrade planes.

d. In an exploratory study, analysis of motion pictures showed that trunk inclination did not change as the subjects became more fatigued.

6. Conclusions

Although there was a definite trend showing the low pack caused greater trunk inclination than did the high pack, the difference between mean angles of trunk inclination was not statistically significant. This trend may be accepted as an explanation of why most men prefer a high pack to a low one.

7. Recommendations

That this study be conducted on a larger group of subjects.

That a comparative study of packs now being used by the U.S. Army and their effect on trunk inclination be made.

8. Acknowledgments

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